DESIGN OF A GAME CONTROLLER FOR PEOPLE WITH MOTOR IMPAIRMENT

Tashko Rizov
Faculty of Mechanical Engineering - Skopje, University "Ss. Cyril and Methodius" in Skopje, Skopje, Republic of North Macedonia
PhD., Associate Professor, tashko.rizov@mf.edu.mk

Risto Tashevski
Faculty of Mechanical Engineering - Skopje, University "Ss. Cyril and Methodius" in Skopje, Skopje, Republic of North Macedonia
PhD., Professor, risto.tashevski@mf.edu.mk

Martin Zhivskovski
Faculty of Mechanical Engineering - Skopje, University "Ss. Cyril and Methodius" in Skopje, Skopje, Republic of North Macedonia
MSc., student, martin.zhivskovski@students.mf.ukim.mk

ABSTRACT

The entertainment industry is one of the largest and most profitable industries today. A great portion of that industry involves video games that are designed with the intent to be played using a game controller. The designers of games usually include options to improve the gaming experience of people with visual or hearing impairments, but the population with motor impairments are left to be dealt by the producers of the game controllers. A number of solutions exist today on the market that tackle this issue, but there is still a good possibility for improvement mainly from the possibilities offered by advanced technologies like 3D printing.

The paper analysis the needed assistance for game controllers for people with motor impairment using the universal design methodology. Furthermore, using the advantages of 3D printing technology, the paper analysis the possibilities for custom design of game controllers according the needs and requirements of the users. After that, the paper presents a design solution for game controller for people with motor impairment together with the methodology for production of a prototype. With a detailed analysis of the improvement effects the game controller introduces to the focus group, the authors conclude on the key elements for design of game controller for people with motor impairment as well as possibilities for further research and development of the product.

Keywords: engineering design; rapid prototyping; 3D modelling; motor impairment;

1. INTRODUCTION

Much progress has been made in building interfaces for people with visual, auditory and motor disabilities, both for day to day activities and for computer interaction. Despite these advances, videogame interaction is highly dependent on hand movement for control. This makes it almost impossible for individuals with motor disabilities to play videogames. In this paper we describe the design of an interaction device for individuals with severe motor disabilities. Through interviews and discussions with a motor-impaired user, we created a device that enables them to play a videogame (Pereira et al., 2011).

Video games, as an entertaining media, dates back to the '50s and their hardware device underwent a long evolution starting from hand-made devices such as the "cathode-ray tube amusement device" up to the modern mass-produced consoles. This evolution has, of course, been accompanied by increasingly specialized interaction mechanisms. As of today, interaction with games is usually performed through industry-standard devices. These devices can be either general purpose (e.g., mouse and keyboard) or specific for gaming (e.g., a gamepad). Unfortunately, for marketing reasons, gaming interaction devices are not usually designed taking into consideration the requirements of gamers with physical disabilities (Maggiorini et al., 2019).

1.1. Video game consoles development

The earliest video game that was publicly presented in 1950 was Bertie the brain (Fig.1-a). It was consisted of a computer tall 4m with vacuum tubes enabling the user to play the well-known tic-tac-toe game. The interaction was with buttons placed in front of the machine. In 1951 at the Britain science festival Nimrod game machine was presented playing the game Nim. In 1958 the first game console is presented, named Tennis for two. The biggest evolution in this industry segment comes in 1971 with the first game designed with integrated circuits – Computer Space. In 1972 on the same hardware design the game Pong is presented – the first coin based game console. In the end of 1972 the first game console that was able to connect to a home TV set was presented. That was the game Magnavox Odyssey and it was sold in 35.000 copies. In 1977 the game console Atari 2600 was presented (Fig. 1-b). This was the first console of the so called second generation with standardized socket for game controller.

(a) (b)

Figure. 1: (a) Bertie the Brain, and (b) Atari 2600
(Source: R. Chikhaniet 2015);

The third generation of video consoles started in 1983 with the boom of Nintendo and Sega. The Nintendo Famicom was the first game console to include a controller with a direction pad. In 1988 for the first time ever Nintendo presented a controller for impaired people. With the continuous development of microprocessors more advanced consoles appear in 1988 which is called the forth generation game consoles. In this generation, Nintendo is the first company to introduce the shoulder buttons on its controller in the Super Nintendo Entertainment System. With the introduction of the CD as a medium the fifth generation of consoles appeared where Sony takes the lead with the Play Station. With the new millennium the sixth generation appears alongside Microsoft's Xbox. The seventh generation of consoles is characterized with motion sensors instead of physical controllers. The last one is the eight generation where the focus is on the social interaction of the players. The three biggest competitors are Nintendo, Sony and Microsoft.

1.2. Video game controllers development

The Tennis for two game developed in 1952 used two controllers, with aluminum casing with one rotating potentiometer and one switch. The potentiometer defined the direction of the ball and the switch was used to give the command to hit the ball. The design in this controller did not play any role since the game was not mass produced. The first commercial game, Magnavox Odyssey introduced the first designed and mass produced controller consisted of three potentiometers and one switch integrated in a plastic box that stands on a flat surface. The revolution comes with the controller of Atari 2600 (Fig. 1-b). This game console had a controller designed according the controls of the aircrafts with so called joystick. His simplicity enabled people who never played a video game to play them with ease and to understand the concept immediately since the movement of the stick was according the desired direction of movement in the game. This controller became a symbol of videogames. The next big innovation was the D-Pad (direction pad) of Nintendo (Fig. 2-a). The joystick was meant for analogue signals, giving simultaneously the command for direction and intensity. For digital signals only the information of the direction was needed therefore the joystick was replaced by the D-pad. With this the player had better control, could change directions faster and the controller had smaller dimensions. Sega for its console Genesis presented the first ergonomic controller (Fig. 2-b). It had a C-shape with buttons placed under an angle making it easier to reach. The next biggest revolution were the motion controllers (Fig. 2-c). With them the interface became wireless and gave a wide array of commands available.

(a) (b) (c)

Figure. 2: (a) Nintendo D-Pad, (b) Sega Genesis and (c) Nintendo Wii motion controller.
(Source: Kyle et al. 2007);

1.3. Disabilities and Video Games

The disabilities as a concept have different meaning in different communities around the World. The disability can be referred to mental or physical properties that some institutions (especially medical) consider that need to be improved. This is referred as medical model. Also, it can refer to the limitations imposed to people by the physical demands of the society – referred as the social model. The United Nations' World Health Organization (WHO) has prepared and International Classification of functioning, disabilities and health that serves as unified platform for describing health and health conditions of an individua (Fig.3). This block-diagram describes human functioning or an individua through three perspectives: body, human and society. The information are organized in two parts: functional disabilities and contextual factors.

The components of the functional disabilities are divided in body functions and structure which also includes anatomic strictures like pain in joint, impaired sight, impaired hearing etc. Activity and participation are components where "activity" is defined as execution of certain task like inability to grasp small objects, lost perception of depth, inability to locate sound etc. Participation is defined as participation in a life situation like socialization, attending a competition, participate in choir etc. Each of these categories are filled in with terms that are chosen from a detailed list which is unified and categorized by short codes.

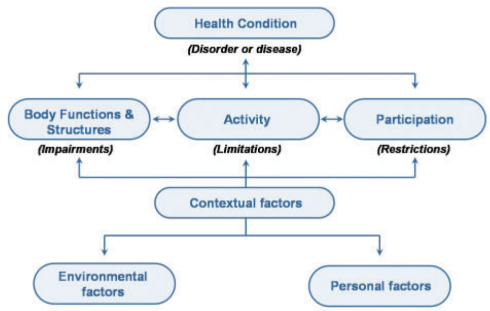


Figure. 3: WHO's International Classification of functioning, disabilities and health.
(Source: WHO. 1980);

The video games accessibility is considered as a separate subgroup of the computer accessibility since video games are a sort of software controlled by specific hardware. Video games accessibility is becoming a major research interest due to two factors: increase of the number of people interested in playing video games and the fact that video games are used for other purposes besides fun, like education, rehabilitation and development. Since video games and gamification are becoming part of formal education, they will have to become accessible to all, including people with disabilities.

Accessibility in video games in general could be categorized in three categories depending on the impairment:

- Could not get feedback from the game due to sensor impairment. For example a user is not able to hear the dialogue between characters in the game, or an audio effect like explosion due to hearing impairment. Similar for visual impairment the player could not recognize the colours or distinct elements of the game.

- Could not provide the needed input signal to the game using conventional device due to physical impairment. Usually, the special devices for input signals for people with physical impairment like the switch controller or the eye tracker are not suitable for games where complex commands are necessary.

- Could not understand the game play or to understand the controls due to cognitive impairment. People with difficulties in learning or poor coordination could have difficulties playing the video games.

The game controllers for impaired people have travelled a significant road of improvement since their beginnings in the 80's. In 1988 Nintendo produced the first game controller for physical impaired people called NES Hands Free . Although it was only made by order and pretty expensive, it was an important milestone in the process of further development of this category of controllers because it caught the attention of other game controllers manufacturers. In the years to come, companies are exploring the combination of voice, electromyography, biting, chin movements etc. One of the latest development in this filed is Microsoft's Xbox Adaptive Controller where by combination of interfaces and programable buttons users can get better game control.

Users, on the other hand, have developed various modifications of the standard controllers to make them suitable for players with physical impairment. By adding specially designed livers or enlargement of the pushing surface of existing buttons. These type of solutions have become more present with the availability of 3D printing. The ability to produce inexpensive plastic parts according custom design have provided users with the ability to make tailor-made controllers according the abilities and impairment of a single user.

Figure. 4: Modifications of standard controllers with custom made masks/elements.
(Source: Maggiorini et al. 2019);

2. DESIGN OF THE CONTROLLER

In order to create a successful product, the universal design (UD) framework has been used. This methodology is most suitable for inclusive design and design for all which are the major elements of our focus. One of the elements of UD are the human factors principals where the accent is on the human-system integration. In order to analyse the human factor principals, the Inclusive Design Toolkit (IDT) was used. This toolkit is specifically focused on the human abilities putting forward the user ability to complete a task. Using the toolkit, the following factors have been analysed: sight (size, shape, contrast, colour, position of graphical versus text elements), sound (volume, tone, clearness, location of sound source), cognitive (memory, interface, attention), reach and agility (force, movement, grasp), mobility (should the user move while using the device).

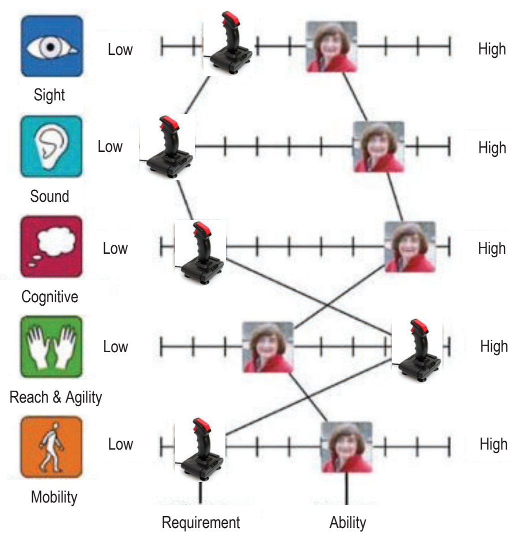


Figure. 5: IDT used to analyse human-system integration.

Each of the factors has been ranged on a scale from low to high for the requirement and ability of a selected focus group (Fig .5). Although this analyse is rough it is a good starting point for the further steps in the design process. In the next steps the "waterflow" method for product development was used in order to precisely define the needs, requirements, concepts and solutions. The user-centric design method was used to analyse the ergonomic properties needed for this product. The final element of the design methodology was the user interview. A focus group of people with motor impairment were selected and a structured interview was conducted. The first target of the interview was to examine different shapes and select the most suitable shape for a controller (Fig. 6).

The second target of the interview was to analyse the difficulties that they face when playing video games. The third target was to investigate if they have made modifications of existing controllers and what can be learnt from that.

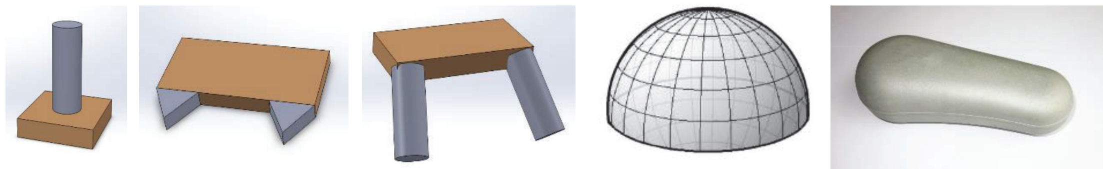


Figure. 6: Different shapes analysed during the structural interview.

The conclusion of the interview was that all users use their hands when interacting with objects, but they all have limited radius of reach. The difficulties they face when playing video games are complexity and reaction speed. This limits them to playing video games controlled only by touch screen. None of the interviewees has made modifications of a controller so far. Regarding the shape, it was a clear selection of the spherical shape as most suitable. The advantage of this shape was that it could be placed on a supporting surface and place the hand over it (Fig. 7). In this way the controller will also support the hand of the user without resulting in joint strain. Also, the fingers have a natural position and the user does not need to move the fingers a lot to reach the buttons of the controller. The spherical shape is most suitable for all users regarding their difference in size of hand making it universal.

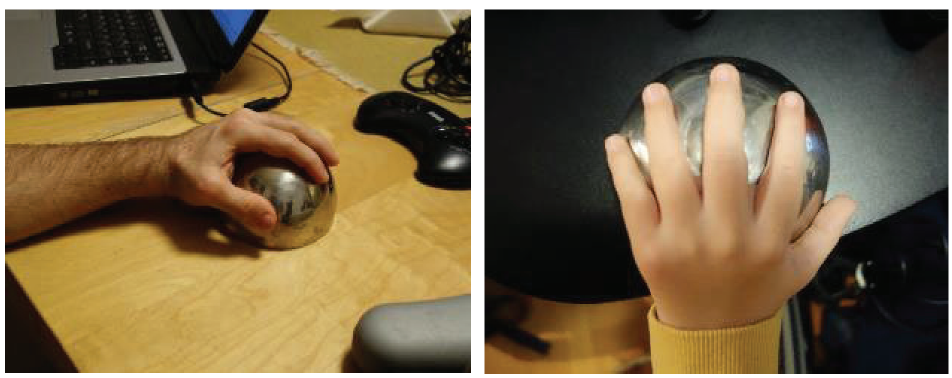
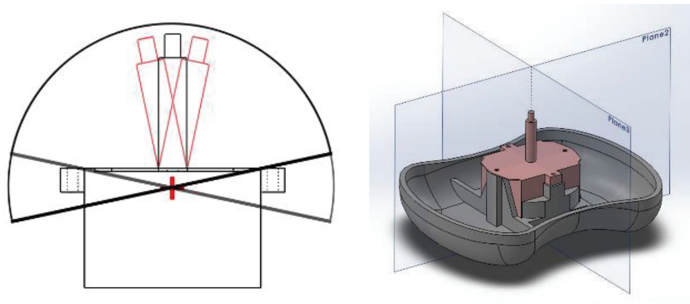


Figure. 7: Spherical shape test while interview with focus group.

Finally, the complete analysis gave the following guidelines for the design of the game controller: spherical shape, use only one hand, support the controller firmly on a surface, use dent buttons, use buttons with higher sensitivity, avoid cylindrical shapes. Having all this in mind, the first sketches of the game controller were created.

The first element of the design was the base of the controller. This element should provide the user with the ability to place the controller on a table and to provide a fix and stable support. Also, the base element has to include the control mechanism and the supporting electronics and switches (Fig. 8-b). By modelling this element in CAD, the best design was selected. For inputting the direction control the system would use a liver that is rotating 12° in each direction. The spherical element was designed based on this function, matching the axis of the two elements to use less force for inputting the command (Fig. 8-a). In order to satisfy the requirement for lower force needed to press the buttons, a microswitch with leaver was selected. The leaver decreases the needed force to activate the switch, i.e. the buttons. Ergonomic research shows that all people have better control on the thumb, the index and the middle finger. The last two fingers are not the best solution for pressing a switch. Having this in mind, this feature was incorporated in the design of the controller.



(a) (b)

Figure. 8: (a) Spherical element with a direction control liver, (b) CAD model of the base element of the controller.

In order to design the dents on the spherical element a clay model was used. The clay element was modelled so it would provide a natural fit of a hand placed on it (Fig. 9). By adding material and changing the radius an optimal shape of this element was achieved. The clay model also served for defining the dents for switch controls as well as the distance between these dents to fit the hand naturally. When an optimal design was achieved the dimensions were recorded and a CAD model was created. In all elements of this process the focus was also to create a controller that can be produced using additive manufacturing technologies. The 3D printing has become so accessible that it this case it could provide with the ability to print spherical elements custom made to the size and shape of the user.

Figure. 9: Clay model of the spherical element to determine optimal dimensions.

3. PROTOTYPE PRODUCTION

In order to produce a prototype the technology for Fused Deposition Modelling (FDM) was used. Using the 3D printer Ultimaker and the accompanying slicer software the three designed elements of the prototype was created. The print out is not used right away, since the shape of the elements is complicated with round edges and wholes. The model is printed with supporting material in order to achieve the desired form (Fig. 10). Also, the model has to be additionally processed in order to achieve the desired quality of the surfaces.

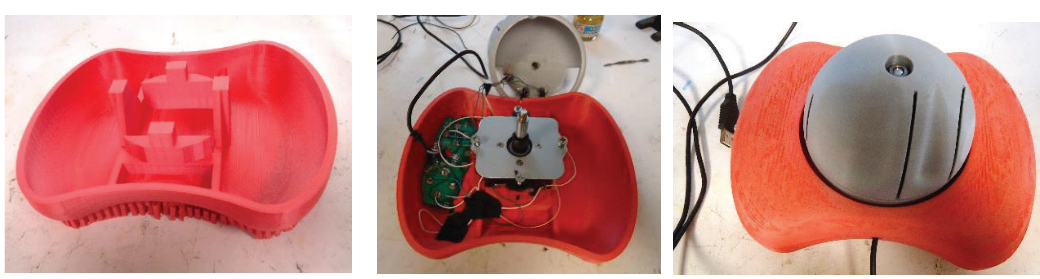


Figure. 10: 3D printed model of the base, subassembly and the final prototype of the controller.

In the next step, the liver for inputting the direction commands is installed, together with the circuit board and the switches for the thumb and the index finger. In the final step, the electronics was wired to the liver and the switches, and the controller was calibrated using the standard tools for controller calibration in Windows operating system. The assembled controller was tested using several video games with different complexity.

4. CONCLUSION

The paper presents the development of video games and video controllers through history focusing on the activities in this area for impaired people. The paper continues with analysis of the International Classification of functioning, disabilities and health that serves as unified platform for describing health and health conditions of an individua. In addition, it utilizes the Universal Design methodology and the Inclusive Design Toolkit to define and determine the requirements of video game players with motor impairment.

Furthermore, using the advantages of 3D printing technology, the paper analysis the possibilities for custom design of game controllers according the needs and requirements of the users. After that, the paper presents a design solution for game controller for people with motor impairment together with the methodology for production of a prototype. With a detailed analysis of the improvement effects the game controller introduces to the focus group, the research provides a list of key elements for design of game controller for people with motor impairment as well as possibilities for further research and development of the product.

REFERENCES

1. Orland Kyle, Thomas Dave, Steinberg Scott. (2007). The Videogame Style Guide and Reference Manual. ISBN 9781430313052
2. Bianca O. Pereira, Cristiano Expedito, Fabrício Firmino De Faria, and Adriana S. Vivacqua. (2011). Designing a game controller for motor impaired players. In Proceedings of the 10th Brazilian Symposium on Human Factors in Computing Systems and the 5th Latin American Conference on Human-Computer Interaction (IHC+CLIHC ’11). Brazilian Computer Society, Porto Alegre, BRA, 267–271.
3. Maggiorini, Dario & Granato, Marco & Ripamonti, Laura & Marras, Matteo & Gadia, Davide. (2019). Evolution of Game Controllers: Toward the Support of Gamers with Physical Disabilities. 10.1007/978-3-030-32965-5_4.
4. Riad Chikhani (2015): The History Of Gaming: An Evolving Community; Techcrunch.com
5. World Health Organisation (WHO). (1980). International Classification of Impairments, Disabilities, and Handicaps, WHO Press.
6. Martin Zhivskovski: Development of methodology for designing a game console controller intended for people with impaired motor functions; University “Ss. Cyril and Methodius” in Skopje (2019).